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ABSTRACT

Performance differences between male and female students in proportional reasoning tasks were analyzed with respect to task characteristics. The student performance was also compared to their visual-spatial ability to determine whether such ability correlates with a better performance. The task characteristics tested were ratio complexity, unfamiliarity of content, and spatial attributes of the tasks. The test subjects came from a suburban school and a mixed urban-suburban school. The results indicate that sex, population, and task characteristics do affect performance on proportional reasoning tasks. Specifically, the complex ratio had more failures than the simple ratio, but no sex dependence was found within each school. Students in the suburban high school did significantly better than those in the mixed urban-suburban school. With respect to unfamiliar versus familiar measuring divices, the interaction with sex was significant at the mixed urban-suburban school with females performing more poorly. (Author/BB)

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SEX DIFFERENCES IN PROPORTIONAL REASONING

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ABSTRACT

Performance differences between male and female students in proportional reasoning tasks were analyzed with respect to task characteristics. The students' performance was also compared to their visual-spatial ability to determine whether such ability correlates with a better performance. The task characteristics tested were ratio complexity, unfamiliarity of content, and spatial attributes of the tasks. The test subjects came from a suburban school and a mixed urban-suburban school. The results indicate that sex, population, and task characteristics do affect performance on proportional reasoning tasks. Specifically, the complex ratio had more failures than the simple ratio ($p < .01$), but no sex dependence was found within each school. Students in the suburban high school did significantly better than those in the mixed urban-suburban high school ($p < .01$). With respect to unfamiliar versus familiar measuring devices, the interaction with sex was significant at the mixed urban-suburban school with females performing more poorly ($p < .05$). Otherwise, fewer failures occurred in familiar tasks than in unfamiliar tasks, but not to a significant level.

BACKGROUND

In a study conducted during the summer of 1976 by the Department of Science Education at Rutgers University in New Brunswick, significant sex differences, favoring males, were found in analyzing students' performance on tasks tapping proportional reasoning.

To determine the possible cause for the differences in performance, it was decided to study proportional reasoning as influenced by task characteristics and by the subjects' sex. The task characteristics chosen for investigation were familiarity of measuring units, complexity of the number

ratios, and a factor which was labelled the "visual-spatial component."

These task characteristics were selected based upon previous research which seemed pertinent to the problem at hand. For example, Julia Sherman has suggested that "sex differences in spatial perception have been neglected as an explanation of sex differences in various aspects of intellectual functioning,"[1] and Maccoby and Jacklin have demonstrated that on tasks involving visual-spatial abilities, boys show a clear advantage over girls.[2] It was, therefore, theorized that the performance differences observed on proportional reasoning tasks might be the result of visual-spatial ability differences. Specifically, it was thought that the "Mr. Tall" task used in the above mentioned Rutgers study might contain a spatial component and that this component influences the proportional reasoning skills to allow boys to do better than girls. It was also theorized that the unfamiliar measuring units used in "Mr. Tall" might contribute to the need for a spatial perception of the problem. For these reasons, familiarity of measuring units and the "visual-spatial component" were chosen as task characteristics to be analyzed.

The complexity of number ratios was included in the study because research performed by Abramowitz showed that some subjects used true proportional strategies to solve simple ratios (1:n, where n is an integer) but failed to use those strategies with complex ratios.[3]

METHOD

Four tasks were used. Each was administered to an approximately equal number of ninth grade boys and girls in two New Jersey high schools, one suburban with a high percentage of professional parents, and the other a mixed urban-suburban school located in a suburban area with urban students bussed in. The tasks included two sets of ratios: 4:6=6/x (the complex ratio) and 4:12=6/x (the simple ratio). These terms were adapted from the

study by Abramowitz. She called ratios of 1½, 1¼, 2/3, etc. "complex multiples" and ratios involving factors of 2,3,etc. "small whole numbers" or "simple multiples." I have used the term complex for the "complex multiples" and simple for the "small whole numbers" or "simple multiples." This is in accordance with her findings that the complex multiples were indeed more difficult for students to perform.[4]

The tasks were set up as follows:

1. spatial measurement with unfamiliar measuring units ("Mr. Tall")[5]
2. spatial measurement with familiar measuring units (carpet)
3. non-spatial measurement with familiar measuring units (cake recipe)
4. non-spatial measurement with unfamiliar measuring units (mud pies)

Students were marked according to the way in which they answered the task on a scale of 0-4 as follows:

0 = completely wrong

1 - additive approach

2 = use of proportionality but wrong numbers used and/or wrong answer

3 = correct answer and/or indication of correct multiplicative value, but not a true proportion

4 = true proportion

When grouped together, the 0-2 categories represented failures, and the 3-4 categories represented the correct responses. This marking system is adapted from the one used by Karplus in which proportional reasoning represents an advanced reasoning stage and additive reasoning represents a less advanced stage.[6]

The number of failures and correct responses were tabulated for males and females for each task. In addition, tabulations were made comparing scores with complex and simple ratios, familiar verses unfamiliar measuring units and spatial versus non-spatial tasks. The spatial relations scores

taken from the Differential Aptitude Test, and other scores from the DAT, were used to correlate with performance. These DAT scores were available, however, only for the suburban school students.

RESULTS

An analysis of the results was done using statistical procedures. A t-Test indicated that the results were significantly different for the two schools ($p < .001$) with the suburban school students performing better. An Analysis of Variance test for the mixed urban-suburban school indicated the following:

1. A significant difference exists between the students' performance with complex as compared to simple ratios ($p < .01$).
2. A significant sex difference exists in overall performance with males performing better ($p < .05$).
3. A significant interaction exists between sex and the familiarity of measuring units with females performing more poorly when the measuring units were unfamiliar ($p < .05$).

A similar ANOVA test with the suburban school did not reveal statistically significant sex differences or significant differences in the complexity of numbers. Correlations with the Differential Aptitude Test (DAT) scores (available only at the suburban school) with the score on the proportional reasoning tasks were high with all aspects of the DAT. The Pearson correlation between the proportional reasoning tasks score and the Space Relations score of the DAT was .79. Using the same procedure, the correlation between proportional reasoning tasks and the combined Verbal and Numerical Abilities from the DAT was .88. The correlation between proportional reasoning scores and the DAT was significant for all subtests ($p < .001$) except for Mechanical Reasoning, ($p < .01$). However, since all subtests of the DAT correlated highly with each other, the DAT is not a sufficiently discriminating test for our purposes. In fact, John Carrol notes in his review of the DAT[7] that there is a disturbing overlap of abilities among the subtests

of the DAT. Specifically, he notes that the abstract reasoning portion of the test is also measuring the student's ability to visualize spatial patterns and shapes. There is also some evidence to indicate that the spatial ability subtest of the DAT loads heavily on abstract reasoning rather than on a spatial factor alone.[8]

The partial correlation between space and score controlling for the combined Verbal and Numerical Abilities is .19. The partial correlations between space and score controlling for abstract reasoning and IQ (Otis Lennon) are .22 and .79 respectively. This supports the notion that the spatial test is measuring "abstract ability."

Eighty-one per cent of the variance in the proportional reasoning scores in relation to the DAT scores can be accounted for by the combined Verbal and Numerical Ability scores and the Abstract Reasoning score. Space Relations, a subtest of the DAT, explains only 0.2% of the variance. However, it is difficult to draw conclusions from these results since the Space Relations and Abstract Reasoning subtests of the DAT measure overlapping abilities.

When the two schools were considered as a group, significant score differences were revealed only for the numbers, the simple numbers being expectedly easier ($p < .01$). Results on the "spatial" verses "non-spatial" tasks were the same within statistical sampling variation.

Since there is some question about the use of the ANOVA procedure for this type of problem, a nonparametric Chi Square analysis of multiple 2 by 2 frequency tables procedure was also used. This method is described by Marasuilo and McSweeney in their text, Non Parametric and Distribution-Free Methods for the Social Sciences.[9] Using this procedure, it was still found that sex interacts with the problem type, producing a difference in score. It was significant ($p < .001$) with nearly all of the sex difference accounted for by the unfamiliar measuring units.

DISCUSSION

The difference in the schools is not too surprising since other investigators have found differences on proportional reasoning scores, with urban students falling behind suburban students.[10] In this study, students in the suburban school performed equally well on all tasks to a greater extent than students in the mixed urban-suburban school.

This appears to indicate that more students in the suburban school have reached formal reasoning in the proportions scheme and that more students in the mixed urban-suburban school are in a transitional stage, between concrete and formal reasoning. For this reason, complex numbers are more likely to confuse students in the mixed urban-suburban school and unfamiliar measuring units have the same effect. This is similar to findings of Smedslund on the concept of conservation of weight. He found that students who had previously acquired the conservation concept ("normally") could not be induced to give up the idea; while those who were just recently taught the concept became confused and readily gave it up when exposed to inconsistencies.[11]

Females, particularly, do more poorly at the mixed urban-suburban school, and sex strongly interacts with unfamiliar measuring units. Since males generally have a more developed visual-spatial ability than females,[12] it is possible that the sex difference with unfamiliar measuring units rests on the visual-spatial difference. That is, it is possible that when a task with unfamiliar measuring units is encountered those with a high visual-spatial ability use this skill to help solve the problem whereas those with a low visual-spatial ability are more often confused. The experiments thus far support this hypothesis but do not prove it conclusively, because visual-spatial scores were not available at the mixed urban-suburban school and because the DAT scores used at the suburban school do not appear,

for the purpose of this study, to be good indicators of the visual-spatial ability.

Sex differences in proportional reasoning abilities related to visual-spatial abilities could have far reaching educational implications, because performance in certain professions such as engineering and architecture is highly correlated with visual-spatial ability. For example, Blade and Watson found that high visual-spatial ability was related to scholastic achievement in terms of graduation for engineering students.[13] A study by Peterson and Sweitzer found that architectural students were more often field independent than other college students.[14] (Field independence and visual-spatial ability have often been correlated. In fact, the EFT and RFT usually used as measures of field independence involve spatial ability. Julia Sherman has suggested that sex differences in various aspects of intellectual functioning, including field independence, may be related to spatial perception.)[15] These sex differences in spatial ability and related performance may account for the fact that more males than females choose other scientific careers.[16]

Performance on spatial tasks has been shown to improve after exposure to training programs. Brinkman found that students improved after a brief programmed instruction course using geometry problems.[17] Blade and Watson found that engineering students improved rapidly when exposed to a program of studies in which only a small portion involved visual-spatial related experience.[18] The Goldstein and Chance study is especially interesting because it indicated that sex differences on the Embedded Figures Test disappeared after training sessions.[19]

In spite of these studies, visual-spatial techniques are not presently taught in any required high school course and electives which include such skills are generally subscribed to more frequently by male students (e.g. mechanical drawing). It is quite likely that females who are exposed to visual-spatial skills will improve these and related proportional reasoning skills and thus expand their professional horizons.

FOOTNOTES

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